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CIVIL ENGINEERING

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DEPARTMENT OF HIGHWAYS

JOINT HIGHWAY RESEARCH PROJECT

FHWA/IN/JHRP-80/4

Final Report

MAINTENANCE METHODS
FOR CONTINUOUSLY REINFORCED
CONCRETE PAVEMENTS

Eldon J. Yoder



PURDUE UNIVERSITY





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TO: H. L. Michael, Director
Joint Highway Research Project

May 14, 1980

FROM: E. J. Yoder, Research Engineer
Joint Highway Research Project

Project: C-36-52K

File: 6-20-11

The following report is submitted on the JHRP research study entitled "Maintenance Methods for Continuously Reinforced Concrete Pavements". This report has been authored by E. J. Yoder.

The research is a cooperative venture in which the Indiana State Highway Commission as well as the Federal Highway Administration participated in planning the research. The construction plans were prepared by the Indiana State Highway Commission. Construction was carried out on I-65 south of Indianapolis. Two Interim Reports have been submitted. These were "Design and Construction of Several Maintenance Techniques for Continuously Reinforced Concrete Pavement", JHRP-76-12, 1976, by Mr. Robert Florence who summarized the construction aspects of the test pavements. Mr. Stanley Virkler authored a report entitled "Maintenance Methods for Continuously Reinforced Concrete Pavements", JHRP-78-1, 1978. This report summarized performance of the test pavements up through the fall surveys in 1977.

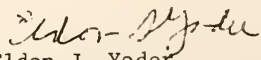
The report by Virkler was submitted on February 28, 1978. At that time it appeared desirable to observe the test pavements during the spring months of 1978. Accordingly, a proposal for extension was prepared under date of April 4, 1978 which would permit making one additional condition survey and deflection measurements during the spring of 1978.

The above work was completed as planned but, in addition, condition surveys were also made in the fall of 1978 and spring of 1979. This report summarizes performance data through the spring of 1979.

This report highlights the research leading up to and including the construction of the test pavements. Summaries are presented of the performance data originally presented by Virkler and extended by the later surveys. The report summarizes cost data which indicate the viability of some of the methods tried; the failures of other methods are discussed as well.

This is the Final Report on this research project and it is submitted to ISHC and FHWA for review and acceptance.

Respectfully submitted,


Eldon J. Yoder
Research Engineer

EJY:ms

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Final Report

EVALUATION OF SEVERAL MAINTENANCE METHODS FOR
CONTINUOUSLY REINFORCED CONCRETE PAVEMENTS

by

Eldon J. Yoder

Joint Highway Research Project

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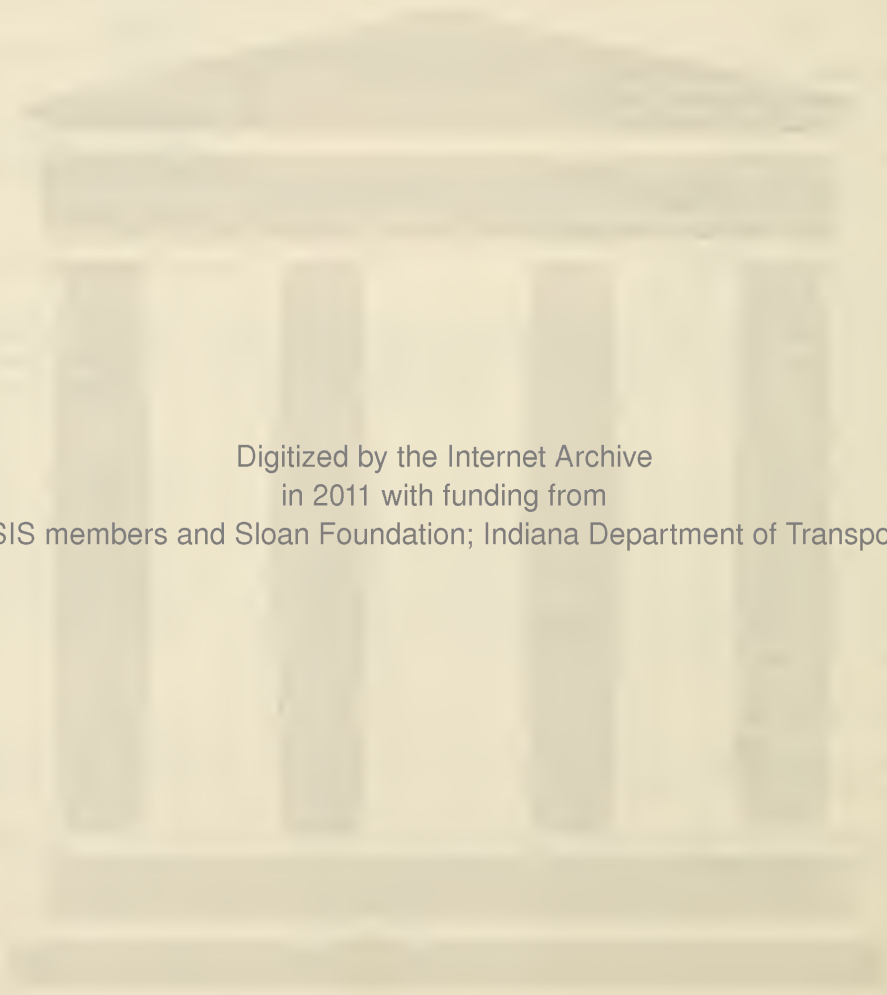
in cooperation with the
Indiana State Highway Commission
and the

U.S. Department of Transportation
Federal Highway Administration

The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Purdue University
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16. Abstract <p>Research on CRCP has been active at Purdue University for the ISHC since 1971. In late 1975, test sections were constructed on a section of I-65 south of Indianapolis, Indiana to evaluate various maintenance techniques that might be adopted for this type of pavement. The road was stratified into "similar" sections using deflection, cracking and breakup as selection criteria. Maintenance methods used included concrete shoulders, undersealing, asphalt concrete overlay, subdrains at the pavement edge and various combinations of these methods. In every case the pavement was patched prior to installation of the maintenance.</p> <p>Performance surveys were made every spring and fall through spring of 1979.</p> <p>The concrete shoulders and subdrains did not reduce the occurrence of distress to this pavement. Undersealing was an effective means of maintaining the pavements.</p> <p>No failures attributable to the underlying CRC occurred on the overlay section during the test period.</p>			
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Final Report

EVALUATION OF SEVERAL MAINTENANCE METHODS FOR
CONTINUOUSLY REINFORCED CONCRETE PAVEMENTS

INTRODUCTION

The use of continuously reinforced concrete pavements in Indiana dates back to 1938 when an experimental project was first built on U.S. 40 near Stilesville, Indiana. Since that time the mileage of continuously reinforced concrete pavement increased until the end of 1971 when 696 miles of equivalent two-lane CRC pavements were in service in the state.

In 1972, a continuing study of the performance of CRC pavements was initiated by the Joint Highway Research Project at Purdue University. The objective of the study was to evaluate and to recommend design and construction techniques that would result in better performance of continuously reinforced concrete pavements.

HISTORY OF RESEARCH ON CRCP IN INDIANA

Primary emphasis was placed on construction of CRCP from the years 1967-1971. By the spring of 1972 it became apparent that severe distress was occurring on some of the pavements.

Purdue University was first contacted in July of 1972 regarding the problem at which time plans were made for a long range research project. A series of 10 papers and reports have been prepared covering the research effort. Specific recommendations were made relative to design changes that might be adopted to improve the performance of this type of pavement.

The research followed a sequential process which culminated in this maintenance study. The list given below is a very brief summary of the approach that was taken.

1. Detailed study of performance on I-65. This was conducted during the summer months of 1972.
2. Statewide performance survey of all CRC pavements in Indiana. This part of the study was conducted in late fall of 1972.
3. Detailed study of selected pavements including field measurements. This portion of the study was conducted in early summer 1973.
4. Laboratory evaluation of materials obtained in step 3 above. This phase of the study was completed in January 1975.
5. Analysis of factors influencing performance. This phase of the study was completed in early summer 1975.
6. Test sections of several types of maintenance were constructed in the fall of 1975 on I-65 south of Indianapolis.
7. The test pavements were evaluated through spring 1979.

Significant Factors Influencing Performance

After several months of research on CRC pavements in Indiana, it became apparent that several factors were showing up as being statistically significant with respect to design and performance of this type of pavements in Indiana. These factors have been discussed in detail in several reports (4,5,6,7)*. The factors influencing the performance of CRCP included (1) subbase type, (2) type of steel fabrication, (3) an interaction of steel placement methods and construction, and (4) traffic.

The following paragraphs discuss some of the features which have been found to influence the performance of these pavements. These factors are not necessarily in the order of importance since it is

*Numbers in parentheses refer to references at the end of this report.

believed that there is no single factor which has influenced performance. Rather, it is a combination of factors that, when combined, have set up a series of circumstances which have caused failures to occur.

Subbase Type

The early surveys showed that pumping was occurring on the pavements which showed the greatest amount of distress. This factor was first reported to the Joint Highway Research Project Advisory Board on September 7, 1972 (1). It was pointed out that most of the pumping was occurring on the gravel subbases and that the crushed stone and slag subbases were apparently showing good performance.

There was a marked increase in defects per mile on I-65 from the summer of 1972 to the fall of 1973 (7). This was true of the gravel subbase sections and the single bituminous stabilized subbase section just north of Lebanon.

Comparison of Subbase Types

Table 1 describes the variation of subbase CBR, permeability, and degree of compaction with subbase type. Though no clear differences in the properties of the gravel subbases were evident between sections with failures and sections showing no apparent distress, the gravel subbases were not sufficiently compacted and had relatively low permeability and strength.

The results brought to light important differences among the properties of the different subbase types. Crushed stone subbases were the most permeable while slag subbases had the lowest permeability. The relatively poor water transmission characteristics of the slag subbase was more than balanced by its high strength, as indicated by CBR.

TABLE 1. EFFECT OF SUBBASE TYPE ON PAVEMENT CONDITION

Type of Subbase	Condition of Test Sections	No. of Test Sections	Subbase CBR		Permeability K	Compaction
			Sampled at Pavement Edge	Sampled at Center Through Core Hole		
Gravel	With Failures	13	33.5%	38.0%	978.9 ft/day*	91.5%**
	Without Failures	10	35.9	45.2	702.6**	93.2**
Slag	With Failures	1	95.0	100.0	30.0	117.2
	Without Failures	3	81.0	96.6	142.9	100.6
Crushed Stone	With Failures	1	32.0	41.0	1369.7	89.9
	Without Failures	1	90.0	59.0	2497.1	85.3

* Average of values from nine test sections.

**Average of values from ten test sections.

NOTE: Data from structurally sound test locations.

Interaction Between Permeability and Strength

It is worthwhile to note that concrete pavement performance is also a function of the interaction between subbase permeability and strength (CBR). In Figure 1, the estimated field permeability values are plotted against field subbase CBR values measured at the shoulder-slab interface. These values pertain to 46 test locations of the detailed field study. Test data for crushed stone and slag subbases are shown with separate indicators. In addition, values obtained at failed-test locations are differentiated from the values at good-test locations. The data were grouped in nine categories corresponding to three levels each of subbase CBR and permeability. For low subbase strength (CBR < 40 percent), mainly gravel subbases, the percentage of failed test locations decreased from 53 percent in the low permeability group ($k < 100$ ft/day) to 25 percent in the high permeability group ($k > 1000$ ft/day). For medium subbase strength (40 percent < CBR < 80 percent), no failures were observed where permeability was greater than 1000 ft/day. Where subbase strength (CBR > 80 percent) was high (applies only to slag and crushed stone subbases) no failures were indicated irrespective of permeability.

It has been suggested in reports submitted to the Indiana State Highway Commission from the outset that pumping is a major contributor to distress to the pavements and that the gravel subbases have shown the poorest performance. The cold-mix bituminous stabilized bases have shown fair to good performance. Recommendations made to the Indiana State Highway Commission on November 10, 1972 (1) included discontinuance of use of gravel subbases and it was suggested that crushed stone subbases (drained) or stabilized subbases should be used. Data obtained suggest slag subbases are showing good performance.

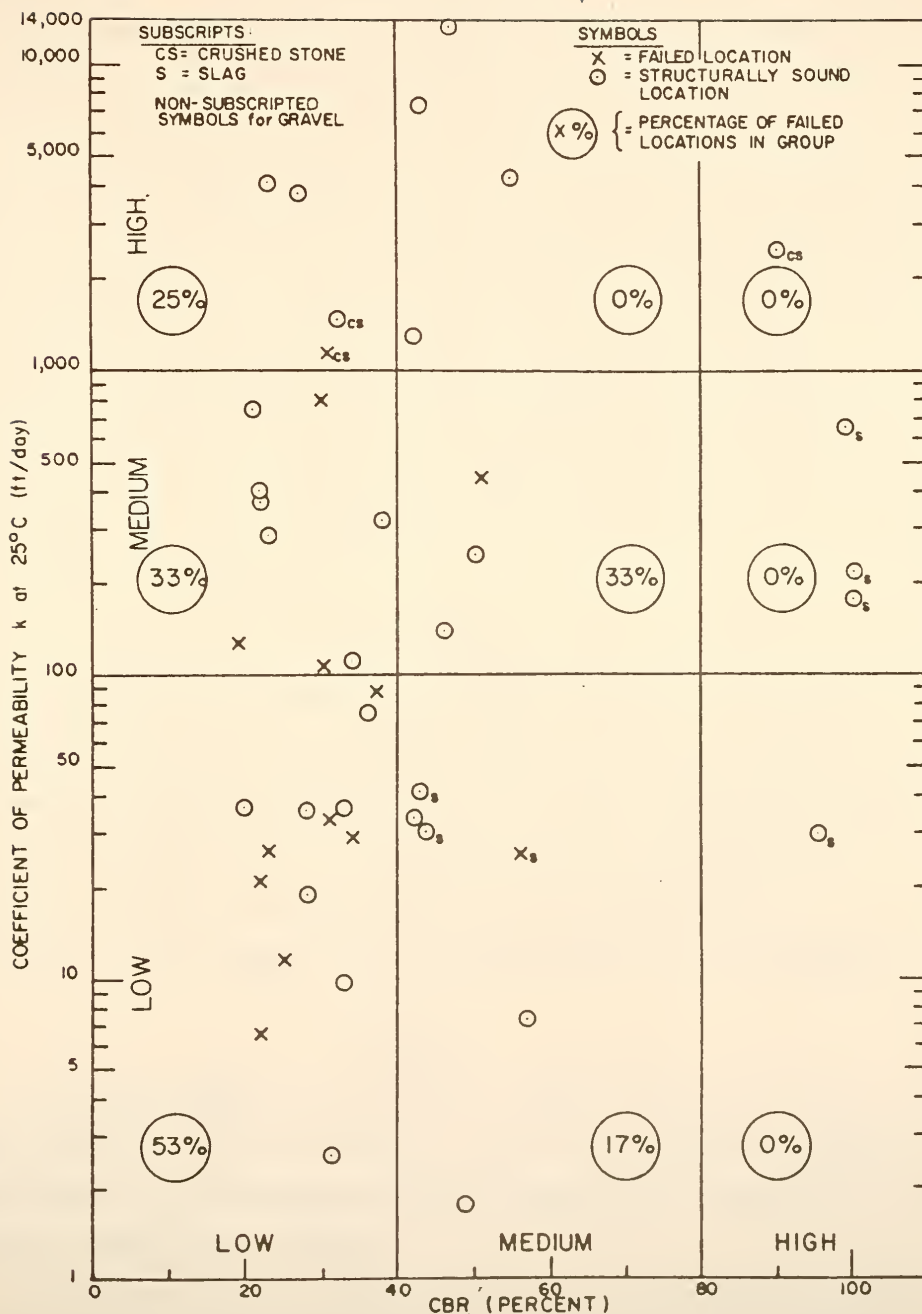


FIG.1. EFFECT OF SUBBASE STRENGTH AND PERMEABILITY ON CRCP PERFORMANCE (FROM FAIZ, REF. 23).

Percent of Steel

Six tenths (0.6) percent steel had been adopted by most states as a standard value for use in CRCP up to the time of this research.

The temperature drop used by the Indiana State Highway Commission for the design of these pavements is 100°F. However in the central and northern portions of Indiana temperature drops from extreme highs during the construction season in mid-summer to winters may go as high as 125°F or greater (7). According to computations of the effect of total temperature drop on required percentages of steel using split-tensile strength values from pavement cores, a temperature drop of 125°F requires more than 0.6% steel. This suggests that 0.6 percent steel was too low for Indiana conditions.

Steel Placement

The survey data have shown that a major contributor to failures occurring on continuously reinforced concrete pavements in Indiana can be associated with use of pre-set steel set on chairs. This was reported as early as September 1972. Recommendations for discontinuance of use of pre-set steel were also made orally to the state in 1972. Performance surveys suggested that bar mats showed poorest performance.

Thickness

The Indiana design has followed the standard recommendations of using a reduction factor of about 0.75. Opinions expressed by various individuals across the United States have suggested that reduction in thickness should not be permitted.

In spite of the lack of substantiating data, it is probable that the thickness design used on CRC pavements in Indiana was at best marginal.

Construction and Other Factors

The above discussion pertains primarily to factors which can be assumed to be in the "design" category. The total research study, however, has dealt with other factors which might affect performance of CRC pavements. Reference is made in particular to the report by Faiz and Yoder (6) which dealt with physical properties determined in the field on selected pavements during the summer of 1973.

Among the more important significant factors was the effect of bulk density of the concrete on performance of the pavements. Concrete at failed locations had lower bulk densities than at good locations. Likewise, the dynamic modulus of elasticity was found to be a contributing factor. On the other hand, the split-tensile strength values were not found to be significantly different between failed and structurally sound locations.

The results of the study showed that there was little difference between the properties above and below the steel reinforcement.

The results of the field survey indicated that no significant difference existed in the mean crack interval as indicated between good and failed locations. It was shown that most of the failed sections were associated with intersecting cracks.

Summary of Field Performance Findings

The comments offered below pertain to the past research on factors which have influenced performance of continuously reinforced concrete pavements in Indiana.

The comparison of test sections with failures as opposed to sections without failures in the detailed field evaluation relative to material properties and performance characteristics evaluated at structurally

sound test locations, resulted in a number of significant results. Similarly the evaluation of section-wide pavement characteristics also established some significant trends. These findings bring to light inherent deficiencies in the pavement structure that eventually lead to distress.

The following is a summary of the significant results (7):

1. Subgrade Properties: The only significant result in the analysis of subgrade properties showed that subgrade soils at sections without failures were relatively more coarse grained and sandy than sections where failures had occurred.
2. Subbase Properties: This analysis clarified the reasons for the better performance of certain subbase types. Crushed stone subbase, at the section without failures was found to possess a high strength (CBR of 90 percent) and excellent internal drainage (over 2000 ft/day). The failure on another section with a crushed stone subbase was a function of poor stability (very low CBR), resulting from inadequate compaction. The good condition of pavements on slag subbases was due to the very high stability (CBR of over 100 percent) of this subbase. At structurally sound locations, gravel subbases were found to have a moderately high permeability but showed poor stability characteristics, probably a function of insufficient compaction.
3. Concrete Properties: It was shown that sections showing no failures were paved with a higher slump concrete. The results of data analysis further indicated that the modulus of elasticity of concrete had a significant bearing on pavement condition. Concrete cores obtained from sections without any distress were tested to have an average dynamic modulus of

elasticity of 6.15 million psi whereas cores, obtained from good locations on sections that had failures, had an average dynamic modulus of 4.97 million psi.

4. Dynamic Pavement Deflection: Dynamic pavement deflections were shown to be a good indicator of pavement condition if used judiciously. Once the continuous slab breaks up into discrete segments, the usefulness of deflections measurements is impaired.

An evaluation of section-wide deflection measurements taken at 6.0 feet from the pavement edge showed that for 9-inch CRCP, dynamic deflections less than 0.5 milli-inches, as measured by Dynaflect, are indicators of good pavement condition. Deflections in the range of 0.6-0.9 milli-inches spell a potential distress condition while values above 0.9 milli-inch are indicators of severe distress with a high probability of pavement breakups.

5. Crack Width: It was noted that crack widths observed at test sections with failures were significantly wider than those measured at good test sections, even though crack widths at only structurally intact locations were measured. The average crack width at good sections was 0.0086 inch.
6. Crack Spacing: No difference in either the mean crack spacing or the variance of crack intervals was observed between sections falling in the two categories. The variance of crack spacing at failed test locations was significantly higher than the variance at good locations. Frequent incidence of bifurcated cracks, as well as closely spaced cracks which may intersect

at a later date, was observed to be associated with failures.

Also, high incidence of very closely spaced cracks is indicative of incipient failure.

PURPOSE OF THE STUDY

It was the purpose of this research to design and construct several different types of maintenance for sections of continuously reinforced concrete pavement. Deflection, the amount of cracking, and the amount of breakups were used as significant indicators of performance and were the basis of selection of the experimental sections.

Previous research on CRC pavements in Indiana suggested that deflections, as measured by the Dynaflect, greater than 0.9 mils are indicative of poor pavement condition. Hence, it follows that the reduction of deflections is one method of reducing potential failure of the pavement. Poor drainage, often caused by the previously mentioned factors was considered to be a major contributor to the high deflection. A third factor was found to be the use of bar mats and pre-set steel on chairs.

A section of I-65 south of Indianapolis, (Contract No. R-8001), was chosen for this project. This section extends southward from the Greenwood exit of I-65 to the Whiteland exit and the test pavements included both the Northbound and Southbound lanes. This resulted in approximately 4.57 miles in each direction or a total of about 9.14 miles of test pavement.

This section was selected for study since it contains all of the significant features identified as major contributors to performance of CRCP. It has a gravel subbase and bar mats and chairs were used. These are three important criteria discussed earlier in this report that indicate potential failure. The grade is relatively flat, soils are

fine grained glacial till, and drainage is generally poor. This pavement has shown, as predicted, very poor performance.

METHOD OF ESTABLISHING TEST SECTIONS

Initial Tests

Deflection measurements and a condition survey of the test pavement were made in the fall of 1974. Deflection readings were taken with the Dynaflect at 25 foot intervals over the study area. The condition survey was made noting the size and location of breakups, and the location and lineal feet of closely spaced parallel cracks, intersecting cracks, and combination cracks. Figure 2 shows the criteria used for determining the lineal feet of cracking. Lineal feet of cracking (L on Figure 2) was the longitudinal distance a specified type of crack was observed.

Method of Selecting Study Sections

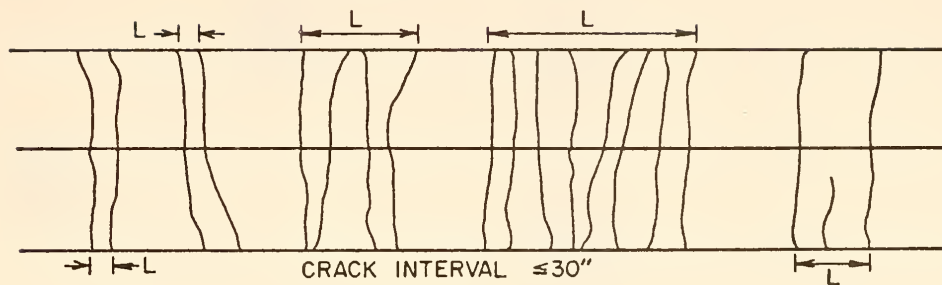
Using the data derived from the above field observations, three factors were chosen as indicative of the overall condition of the pavement. These were: (1) lineal feet of cracks spaced less than 30 inches plus lineal feet of intersecting cracks per 100-foot station, (2) total area of patching or breakups per station and (3) maximum deflection per 100-foot section.

Using this technique, the sections of pavement were then stratified and assigned rating numbers of 1 to 12 as shown in Figure 3.

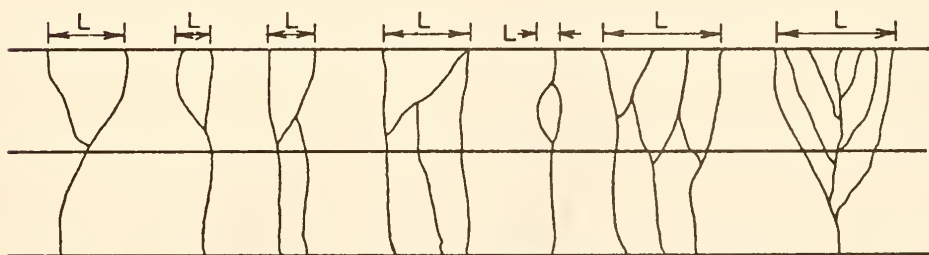
Selection of Maintenance Methods

Tables 2 and 3 show the types of maintenance that were considered to be appropriate for the given rating numbers. This list was used as a "shopping list" from which maintenance types could be chosen. An attempt

PARALLEL CRACKS



INTERSECTING CRACKS



COMBINED PARALLEL AND INTERSECTING CRACKS

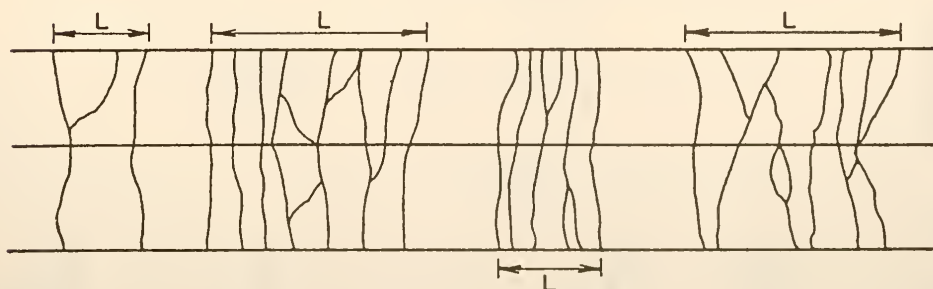


FIGURE 2. TYPICAL CRACK PATTERNS

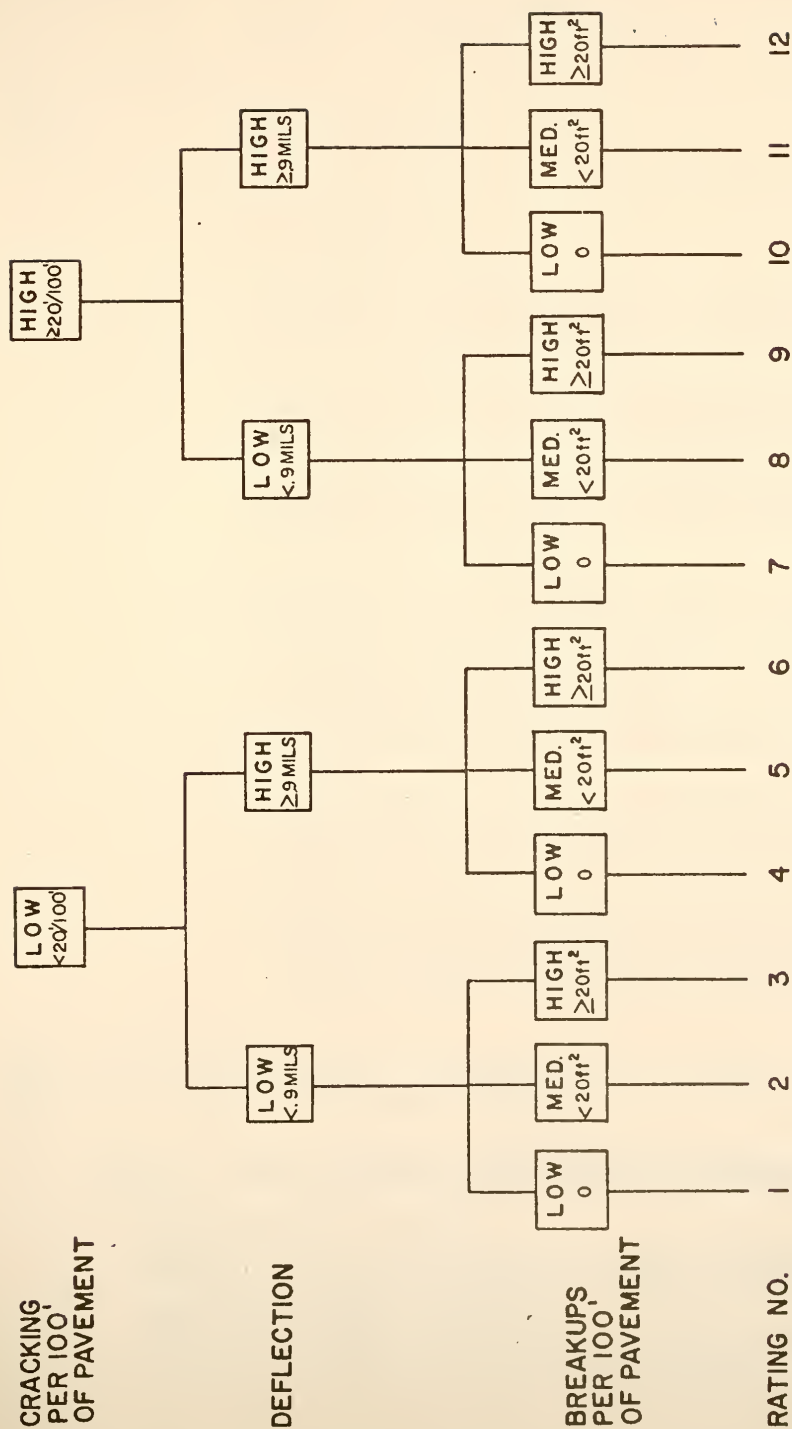


FIGURE 3. RATING OF TEST SECTIONS

TABLE 2. POSSIBLE MAINTENANCE*

Rating No.	Type of Maintenance
1	No Maintenance
2	No Maintenance; Patch
3	No Maintenance; Patch
4	No Maintenance; Underseal & Overlay, Underseal; Overlay; Concrete Shoulders; Drain
5	No Maintenance; Patch, Underseal & Overlay; Patch & Underseal; Patch & Overlay; Patch & Concrete Shoulders; Patch & Drain; Patch, Drain & Concrete Shoulders
6	No Maintenance; Patch, Underseal & Overlay; Patch & Underseal; Patch & Overlay; Patch & Concrete Shoulders; Patch & Drain
7	No Maintenance; Drain; Overlay
8	No Maintenance; Patch & Overlay; Patch & Concrete Shoulders; Patch & Drain; Patch
9	No Maintenance; Patch & Overlay; Patch & Concrete Shoulders; Patch & Drain; Patch
10	No Maintenance; Underseal & Overlay; Concrete Shoulders; Drain
11	No Maintenance; Patch, Underseal & Overlay; Patch & Drain; Patch & Concrete Shoulders; Full Depth Bituminous
12	No Maintenance; Patch, Underseal & Overlay; Patch & Drain; Patch & Concrete Shoulders; Full Depth Bituminous; Patch, Underseal, Overlay, Drain & Concrete Shoulders; Patch, Drain & Concrete Shoulders

*Note that the table presents a "shopping list" of possible maintenance. These were varied to fit construction needs.

TABLE 3. POSSIBLE PRACTICAL COMBINATION OF TECHNIQUES

1. Underseal prior to overlay.
2. Underseal prior to construction of concrete shoulders.
3. Install drains prior to overlay.
4. Install drains prior to construction of concrete shoulders.

was made to apply as many types of appropriate maintenance as possible to the various ratings, but all the types of maintenance were not used in some cases. The list was compiled during a conference of personnel from Purdue University, the Indiana State Highway Commission and the Federal Highway Administration.

Layout of Study Sections

The layout of study sections of a given maintenance type was governed by four criteria:

1. All sections were patched as a minimum.
2. It was desirable to make a section of one type of maintenance as long as possible.
3. Retain at least 1 "control section" for each rating number 1 → 12. These control sections were patched as needed.
4. Use as many different types of maintenance methods as possible for each rating number.

MAINTENANCE METHODS USED

During construction of the maintenance, Purdue personnel were present, serving in an advisory capacity and working closely with the Indiana State Highway Commission field personnel. The maintenance sections were constructed using standard techniques of the Indiana State Highway Commission under the supervision of project engineers as is normally done. Purdue personnel merely advised where needed on technical matters arising during the construction.

All of the breakups on the project were patched with concrete regardless of type of maintenance used. This is with the exception of those sections which were designated bituminous patch sections wherein

bituminous patches were used in lieu of concrete patches for the purpose of evaluating these and the "no maintenance" sections which required no maintenance at all. Figure 4 shows the as-built maintenance sections as they were finally constructed.

Concrete Shoulders

The intent of the concrete shoulders was to stiffen the pavement thereby reducing deflection and subsequent pumping and failure of the pavement. The concrete shoulders were constructed with contraction joints spaced at 15 foot intervals. The slabs were 6 inches thick on the outside edge and 9 inches thick on the inside edge. They were tied to the existing pavement with 30 inch long No. 4 tie bars.

The tie bars were spaced at three different intervals, 1 foot, 2 feet, and 2 feet 6 inches, on centers. One section, 1,200 feet in length, was tied into an existing keyway whereas the remaining 2,010 feet were tied to the vertical face of the pavement thus forming a butt joint. The tie bars were omitted 2 feet 6 inches on either side of the construction joints to permit independent movement between the existing CRC pavement and the concrete shoulder.

After excavation and grading of the existing asphalt concrete shoulder, holes were drilled into the existing pavement to a depth of 14 inches with a tractor mounted drill. The tie bars were grouted into the existing pavement with a combination of epoxy and a non-shrinking grout. Details of the technique are presented by Florence (9).

Rumble strips were installed every 60 feet along the concrete shoulder. Construction joints were installed at the end of each day's pour. These joints were always located at the middle of a slab and tied with tie bars.

SECTION	SBL	
	1235	1235 - 00
Q		CONCRETE PATCHING WHERE NEEDED
		1224 - 00
P	1220	CONCRETE SHOULDER
		1212 - 00
		BRIDGE
O		NO MAINTENANCE
		1206 - 00
N	1200	BITUMINOUS PATCHING FULL DEPTH
		1204 - 00
		1196 - 00
M		CONCRETE PATCHING WHERE NEEDED
	1180	1171 - 00
		1160
L		UNDERSEAL AND OVERLAY
	1140	1141 - 00
		1100
K		CONCRETE PATCHING WHERE NEEDED
	1100	1090 - 00
		1080
J		UNDERSEAL
	1060	1059 - 00
I		SUBDRAINS
		1050 - 00
		1040
		UNDERSEAL AND OVERLAY
G		CONCRETE PATCHING
		1036 - 00
		1033 - 05
F		SUBDRAINS AND CONCRETE SHOULDER
	1020	1018 - 50
E		CONCRETE SHOULDER
		1008 - 00
D		CONCRETE PATCHING WHERE NEEDED
	1000	1001 - 00
C		NO MAINTENANCE
B		996 - 00
A	990	CONCRETE PATCHING
		995 - 00
		990 - 00

SECTION	NBL	
	1235	1235 - 00
HH		OVERLAY
	1220	1212 - 00
		BRIDGE
		1206 - 00
	1200	CONCRETE PATCHING WHERE NEEDED
GG		1180
FF		NO MAINTENANCE
		1176 - 00
EE		UNDERSEAL
		1172 - 00
DD		SUBDRAINS
		1167 - 00
CC	1160	1161 - 00
		NO MAINTENANCE
		1152 - 00
BB		OVERLAY
		UNDERSEAL AND OVERLAY
AA		1148 - 00
		1143 - 00
Z	1140	OVERLAY AND SUBDRAINS
		1136 - 05
		1100
Y		OVERLAY
	1100	1101 - 00
X		UNDERSEAL AND OVERLAY
		1082 - 00
W	1080	CONCRETE PATCHING
V		CONCRETE SHOULDER
U		1072 - 00
		1066 - 00
	1060	SUBDRAINS AND CONCRETE SHOULDER
		1065 - 00
		1040
T		SUBDRAINS
	1020	1025 - 00
		1000
S		CONCRETE PATCHING WHERE NEEDED
	1000	994 - 00
R	990	NO MAINTENANCE
		990 - 00

FIGURE 4. AS BUILT MAINTENANCE SECTIONS

NOTE: CONCRETE PATCHING SECTIONS WERE CONTROL SECTIONS FOR THE VARIOUS MAINTENANCE TYPES.

General Observations

1. About every other joint in the concrete shoulder cracked after about 5 days.
2. A small amount of honeycombing was noticed at the outside edge of the concrete shoulder in some locations.
3. Some of the drivers used the concrete shoulder as a riding lane during the construction period. This, however, was discontinued after the entire pavement was opened to traffic.

Subdrains

One of the major contributors to performance of this pavement was pumping which resulted from free water on top of the subbase. For this project subdrains were installed directly adjacent to the pavement edge. This was done in an effort to trap and remove water from the top of the subbase as quickly as possible and to drain infiltration water between the pavement and shoulder.

The backfill for the subdrains was carried up beyond the bottom edge of the pavement and to within 3 inches of the top of the pavement. The top 3 inches was filled with asphaltic concrete shoulder material.

General Observations

1. Several days after the subdrains had been installed water was noticed draining from the outlets.
2. The subdrains were installed deeper than necessary for drainage of the subbase and, hence, are possibly removing some ground water as well as water from the subbase.

Undersealing

Since pumping was considered to be one of the primary modes of failure for this pavement, undersealing (both with and without overlaying with asphalt concrete) was a major variable in the experimental layout. The underseal was intended to fill voids that might exist between the pavement and subbase.

The pavement was undersealed with asphalt at specified locations. Two inch diameter holes were drilled through the pavement in the right hand lane. After pumping the hole was filled with a wooden plug.

Criteria for Spacing Holes

When the undersealing operation first began, the proper spacing of the holes was not known. Hence, it was necessary to establish criteria which could be used by the contractor for spacing of the holes and pumping of asphalt with a minimum of delay during the construction process.

In general, one row of holes spaced 8 feet on centers was used at locations where deflections were greater than 0.9 mils with uniform crack spacing. Two rows staggered every 4 feet were used at locations with high deflections associated with closely spaced cracking. At least two holes were drilled on each side of a potential failure or on each side of potential patches.

If the deflection was less than 0.9 mils, the pavement was not undersealed. Hence, in the underseal sections, some of the pavement was not undersealed depending on deflection. Data shown in subsequent paragraphs (Table 7) suggest the value of 0.9 mils is probably conservative since some distress is found on sections actually not undersealed. For prevention of further failures a lesser value should be used, but this would increase cost.

After several sections were undersealed, it was decided that just one row of holes spaced 8 feet on centers in the centerline of the right hand lane was needed since the asphalt was traveling across and coming out the staggered holes. The final quantities of undersealing on this construction is shown in Table 4. It is to be noticed in Table 4 that quantities of undersealing material actually used decreased as the work progressed. The contractor had some difficulty on the third day and hence the actual weight of asphalt pumped was decreased. Referring to Figure 4, undersealing was started at station 1171+00 on the southbound lane and progressed in a southerly direction. From there the undersealing was continued on the northbound lanes and the last section sealed was between stations 1167+00-1172+00 (Section EE). Hence, it is noted that the actual quantities of asphalt used on the northbound lanes on Section EE was less than that used on other sections. This is believed to have significant influence on the results.

Details of the undersealing criteria have been outlined by Florence (9).

TABLE 4. QUANTITIES OF UNDERSEALING MATERIAL

Day	No. of Holes Pumped	Weight of Asphalt Pumped
1	238	16.94 tons
2	224	11.76 tons
3	102	1.22 tons

Asphalt Concrete Overlay

The intent of the asphalt concrete overlays was to reduce deflection but, in addition, to perhaps prevent infiltration of water and improve

performance from this. It was not known at the time of construction how thickness of overlay might influence performance particularly from the standpoint of reflection cracking. Therefore thickness of overlay was included as one of the variables of the experiment.

As can be seen from Figure 4 overlay was used on the southbound lanes in section H and L. In the northbound lanes the primary overlay areas were in sections X and Y.

In general, a standard thickness of overlay of 3 inches was used except as noted below. The existing pavement was overlaid using a bituminous base of 370 pounds per square yard (approximately 3 inches) on all locations except the longest overlay on the northbound lane between stations 1082+00 to 1152+00 (sections X to BB). In this section an overlay wedge was formed by varying the base thickness as shown in Table 5.

TABLE 5. OVERLAY THICKNESS IN NB WEDGE SECTION

Station Limits	Amount and Thickness
NBL 1082+00-1110+00	220#/syd. (approx. 2 inches)
NBL 1110+00-1119+00	370#/syd. (approx. 3 inches)
NBL 1119+00-1129+00	550#/syd. (approx. 5 inches)
NBL 1129+00-1152+00	370#/syd. (approx. 3 inches)

This operation was performed by installing 1 inch of bituminous base where 3 inches was required, 3 inches of bituminous base where 5 inches was required, and then adding 2 inches of base over the entire section giving the required thickness throughout the wedge.

The existing shoulders were overlayed with a No. 53B bituminous base to the required depth. The bituminous base over the pavement was finally overlayed with a 70 pound Type IV emulsion surface and the shoulders were sealed with a Type II sealant to complete the overlay operation.

Concrete Patching

As mentioned previously concrete patching was required on all sections as a basic form of repair prior to the placing of any subsequent maintenance type. This is with the exception of Section N where the basic experiment called for full depth bituminous patching. The layout of the experiment required that any location where breakup had occurred must be patched in addition to any other maintenance that was used.

Referring to Figure 4 it is noted that several "no maintenance" sections were in the experiment. These were sections of pavement that were considered to be in good repair and they required no maintenance at all. Hence, they are excluded from all further analysis.

Observations

The concrete patches were installed using standard procedures. Four grooves were first cut in the pavement. The first two cuts were about 2 inches deep at the outside of the area to be patched. The second two cuts were to a depth of 5 or 6 inches. These cuts were approximately three feet inside the outside edge of the potential patch, thus leaving exposed three feet of steel on each end of the patch to be tied to the new reinforcing steel.

No. 5 reinforcing bars were tied to the existing longitudinal No. 4 bars and were set on chairs. Transverse bars were tied to longitudinal bars at about 3 foot intervals to keep the longitudinal bars stationary during the pouring of the patch.

The patches were poured directly from the concrete truck. They were vibrated with a hand-held vibrator, leveled off, brushed and left to cure.

Areas of potential failure were judged individually by the ISHC project engineer. Some of the potential failures were patched and some were left unpatched depending upon his judgment as to the extent of the damage.

As a general observation some of the patches failed one year after construction. These were evaluated further using the Dynaflect and replaced. In some cases, the existing CRC pavement "upstream" of the patch failed and at other times the patch itself failed. This is believed to be due to a variety of reasons primary of which is inaccuracies of delineating the exact extent of serious defects.

Full Depth Bituminous Patching

Full depth patching was included to compare the effect of bituminous patching with that of the concrete patching previously discussed. A minimal amount of this was used. In addition, however, during the subsequent maintenance of the pavement bituminous patches were placed if small failures existed.

The full depth bituminous patches were constructed similar to the concrete patches, however, all of the existing steel within the patched area was removed along with the concrete to the pavement depth. After compacting the subbase, a No. 5 asphalt base was installed with a Type B surface bringing the patch back to the existing grade.

COST DATA

Comparisons of cost of the various maintenance methods have been presented in detail by Florence (9). The cost data include that required

for all functions of the construction including patching, materials and all other factors normally considered in construction of this type.

In addition to the above, Virkler (10) has presented a breakdown of the cost data on the basis of type of maintenance using as a unit of measure the cost in terms of dollars per 100 feet of two-lane pavement. Data presented in terms of lineal feet of pavement permit an easy comparison of costs and analysis of the cost effectiveness of the various types of maintenance.

Further reference to the cost of maintenance in terms of dollars per 100 feet is used in this report and is presented in Table 8 where performance of the various test sections is presented. All subsequent analyses are presented in terms of unit costs as described herein.

PERFORMANCE SURVEYS

The maintenance test sections were completed in the fall months of 1975. Due to climatic conditions it was not possible to place the antiskid surface on the overlay sections during the fall and this was done the following spring. Likewise, some of the ancillary work (painting, etc.) was also completed the following spring.

A complete performance survey including logging of the extent of failures, cracking and measurement of deflection using the Dynaflect was made immediately prior to construction of the test sections. The performance surveys were repeated immediately following construction of the test sections and then were again repeated each spring and fall up to the fall of 1977.

The performance surveys included complete logging of the extent of cracking that had occurred, logging of the failures that took place and measurement of deflection using the Dynaflect at 25 foot intervals. Deflections were made using just the sensor immediately under the vibrating wheels of the Dynaflect.

Special Deflection Measurements

In addition to the detailed performance surveys which were made each spring and fall, a special program of measuring deflections at areas adjacent to concrete patches was carried out in the spring of 1976. The reason for these special deflection measurements was that it was felt at that time that a relatively large amount of the concrete patches themselves were failing or additional failures were occurring just adjacent to concrete patches. In general, failures that occurred next to concrete patches occurred in the upstream direction of traffic (at the leading edge of the patch as vehicles approached) and there was some question whether or not the original concrete patches were extended far enough in each direction.

Continued Performance Surveys

Performance surveys were made each spring and fall after construction up through the spring of 1979. The work plan called for deflection measurements and performance surveys through spring 1978. This work was completed as planned.

Performance surveys were made in the fall of 1978 and spring 1979 without deflection measurements. For these two periods of time the surveys consisted of logging failures alone. In the analysis, primary emphasis was placed on the failure logs.

RESULTS OF PERFORMANCE SURVEYS

Failures

An important facet of determining the performance of CRC pavement involves analyzing the number and location of failures (primarily punch outs). The ISHC District personnel determined whether a damaged area was actually a failure or not. This was in accordance with the "ground rules" established at the start of the project.

Failures Adjacent to Patches

During the first winter after construction of the test sections, it was found that many patches themselves either failed or failures had occurred ahead of or behind the patch. Therefore, each patch was observed in order to determine the percentage of failures associated with patches. This was done for both the 1976 and 1977 failures.

The results of the special study which determined the association of new failures with old failures is as given below:

Total Failures	112
Isolated Failures	68
Failures at Concrete Patches	43
Failures at Bituminous Patches	1

Because of the apparent high incidence of failures adjacent to patches, it was agreed at a meeting in April 1976 that additional deflection measurements should be taken 40 feet before and after the area of every failure. These results, hopefully, would help determine where the patch should begin and end. A deflection greater than 0.9 mils was used as a criteria for patching that area.

Special Surveys of Failures in the Concrete Shoulder Sections

Special observation was also made of patches within the sections with concrete shoulders. It was believed after the first winter of performance that more failures were tending to occur in the continuously reinforced concrete pavement adjacent to the joint in the concrete shoulder than were occurring at mid points between the joints in the concrete shoulder. It was also believed that there were more failures associated with the 12-inch tie bar spacing than the 24-inch and 30-inch tie bar spacing.

A summary of the 1976 results are as shown below:

Total Failures in Concrete Shoulder Sections	15
Failures in sections with 12-inch tie bar spacing	4
Failures in sections with 24-inch tie bar spacing	6
Failures in sections with 30-inch tie bar spacing	5

As can be seen from the above there is little association with the number of failures that occurred relative to the spacing of the tie bars in the pavement edge itself. The data would suggest that occurrence of failures bears no relationship with tie bar spacing and therefore greater tie bar spacings may be used on this type of construction. On the other hand, it can be argued that the concrete shoulders themselves were ineffective in preventing additional failures. It should be recalled that this particular section of pavement (primarily at the southern end of the south bound lanes) had shown very poor performance prior to construction of the maintenance sections and hence factors such as subgrade, subbase and others could be major contributors to performance in this situation.

In any event, the concrete shoulders in this particular situation were not considered to be an effective means of preventing additional failures.

Relative to the occurrence of failures adjacent to joints and in midspan the 1976 data are summarized below:

Total number of failures	15
Failures adjacent to joints in the concrete shoulder	8
Failures at mid-span of the concrete shoulder joints	7

On the basis of the above it is to be seen that the occurrence of failures either adjacent to a joint or a midspan were about evenly distributed.

Progression of Failures with Time

Figure 5 shows the number of failures that have occurred on the test pavement during various time periods. Before the test pavements were constructed 102 failures had occurred over the entire section and 112 additional failures occurred two years after the test sections were constructed. It should be recalled that this test pavement is considered to be a severe test since it contained most of the features that have been known to contribute to poor performance of CRCP in the state of Indiana.

The occurrence of failures bore a relationship with the season of the year. The data showed that a large portion of the failures occurred during the fall-winter-spring months and that the occurrence of failures was reduced over the summer periods (see Table 6).

Results of Failure Surveys

Solely on the basis of the occurrence of additional failures after construction of the test sections, the data indicated that the overlay sections have performed better than any of the other test methods. A summary of failures that have occurred since construction of the test sections is listed in Table 7. In this Table the data are arranged in descending order relative to number of failures per 100 ft.

It is apparent when looking at these data that the concrete shoulders were not effective in this particular experiment nor were the subdrains. A large portion of the concrete shoulder sections were concentrated at the southern end of the south bound lanes where poor performance had been demonstrated prior to the experiment and hence the data may be influenced by factors other than the use of shoulders themselves.

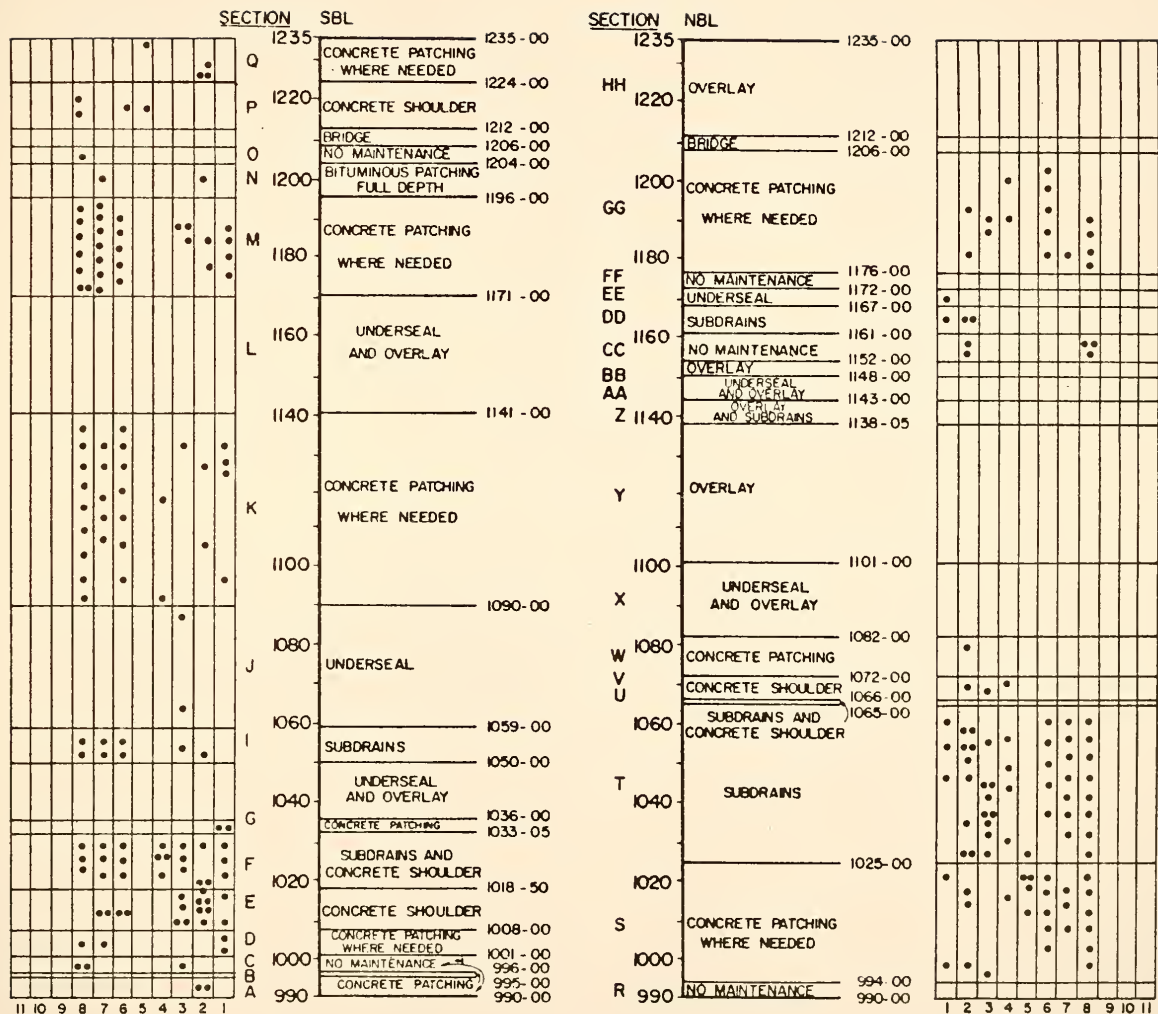


FIGURE 5. FAILURE AS A FUNCTION OF LOCATION AND TIME

NOTE: CONCRETE PATCHING WAS DONE WHERE NEEDED IN ALL AREAS EXCEPT NO MAINTENANCE AREAS.

1. Aug. 75 - March 76
2. March 76 - Aug. 76
3. Aug. 76 - Dec. 76
4. Dec. 76 - July 77
5. July 77 - Oct. 77
6. Oct. 77 - April 78
7. April 78 - Oct. 78
8. Oct. 78 - June 79

TABLE 6. FAILURES AS A FUNCTION OF SEASON

Period of Survey	Season	% Total
1. Aug. 75-March 76	Winter	(10.5)
2. March 76-Aug. 76	Spring-Summer	17.5
3. Aug. 76-Dec. 76	Fall-Winter	(12.3)
4. Dec. 76-July 77	Winter-Spring	(6.1)
5. July 77-Oct. 77	Summer	3.1
6. Oct. 77-April 78	Fall-Winter	(15.7)
7. April 78-Oct. 78	Spring-Summer	13.6
8. Oct. 78-June 79	Fall-Winter	<u>(21.2)</u>
		100

65.8% occurred during Fall-Winter-Spring.

34.2% occurred during Spring-Summer.

TABLE 7. SUMMARY OF FAILURE DATA

Maintenance Method	Failures per 100 feet	
	Through Fall 1977	Spring 1979
Underseal		
2" overlay	0	0
Underseal		
3" overlay	0	0
2" overlay	0	0
3" overlay	0	0
5" overlay	0	0
Subdrains		
3" overlay	0	0
Underseal	0*	0*
Bit. Patch	0.125	0.285
Subdrains	0.527	1.000
Conc. Shoulders	0.560	1.960
Subdrains and Concrete Shoulders	0.890	1.506
Control Sections	0.240	0.505

*Several failures have occurred in the underseal section but not at locations actually undersealed.

The subdrains that were installed in this particular test project were relatively deep and are no doubt draining the subgrade as well as the subbase. The back filling operation adjacent to the pavement edge was always carried up to the mid-depth of the concrete pavement and, therefore, any water that lays on the subbase should drain through the drains. It is known that the drains are functioning. However, the subbase under the pavement is impervious and contains a high percentage of fines. Therefore, rapid percolation of the water through the subbase itself is probably not taking place and any water that is drained from the subbase is that which lies at the pavement-subbase interface.

Deflection Measurements

Pavement deflections were measured with the Dynaflect. The Dynaflect applies a repetitive rate of 8 cycles per second to the pavement through two wheels.

From Faiz's study (7) measurements taken six feet from the pavement edge showed that for 9 inches CRCP, deflections less than 0.5 mils are indicators of good pavement condition. Deflections in the range of 0.6-0.9 mils indicate a potential distress condition, while values above 0.9 mils are indicators of severe distress with a high probability of pavement breakups.

Deflection measurements were taken in this study for four uses. The first was to compare the deflections as a function of time across each section. A second was to permit a statistical analysis of maintenance methods and the third purpose was to evaluate the effectiveness of the concrete patches. The fourth reason was to determine the significance of keyed versus non-keyed concrete shoulder sections and the significance of the deflection associated with the joint of the shoulder versus the deflection between the joints.

Deflection Versus Time

Figure 6 shows a generalized plot of deflection for the various sections as a function of time. Several general comments can be made relative to these data. It is to be seen that the deflections between August of 1975 and October 1975 decreased a marked amount. This was the interval of time of construction of the test pavements and the reduction in deflection is indicative of the effects of the treatments themselves. However, some general stiffening of the subgrade may have resulted during the autumn months and this may have had an effect as well.

For purposes of illustration the heavy line indicated with a number 3, shows the average deflection of the control sections (those that had concrete patching only) as a function of time. The deflection of these sections remained essentially constant throughout the time span after the construction period in autumn of 1975.

In contrast to this, the sections indicated by the numbers 2, 6, and 9 are those represented by the overlay pavements with and without underseal. Here it is seen that the deflections decreased with time. It is to be recalled that these sections have also showed excellent performance. In contrast to this, the curves indicated with numbers 5 and 10 are illustrative of the deflection patterns of the drainage and concrete shoulder sections which showed considerable amount of failure during the test period.

Special Deflection Measurements

The first year after the sections were constructed, a relatively large amount of failures appeared and in some cases these were associated with previous patches and in other cases the patches themselves failed. Of a total 112 failures during the first year, 68 of these were isolated

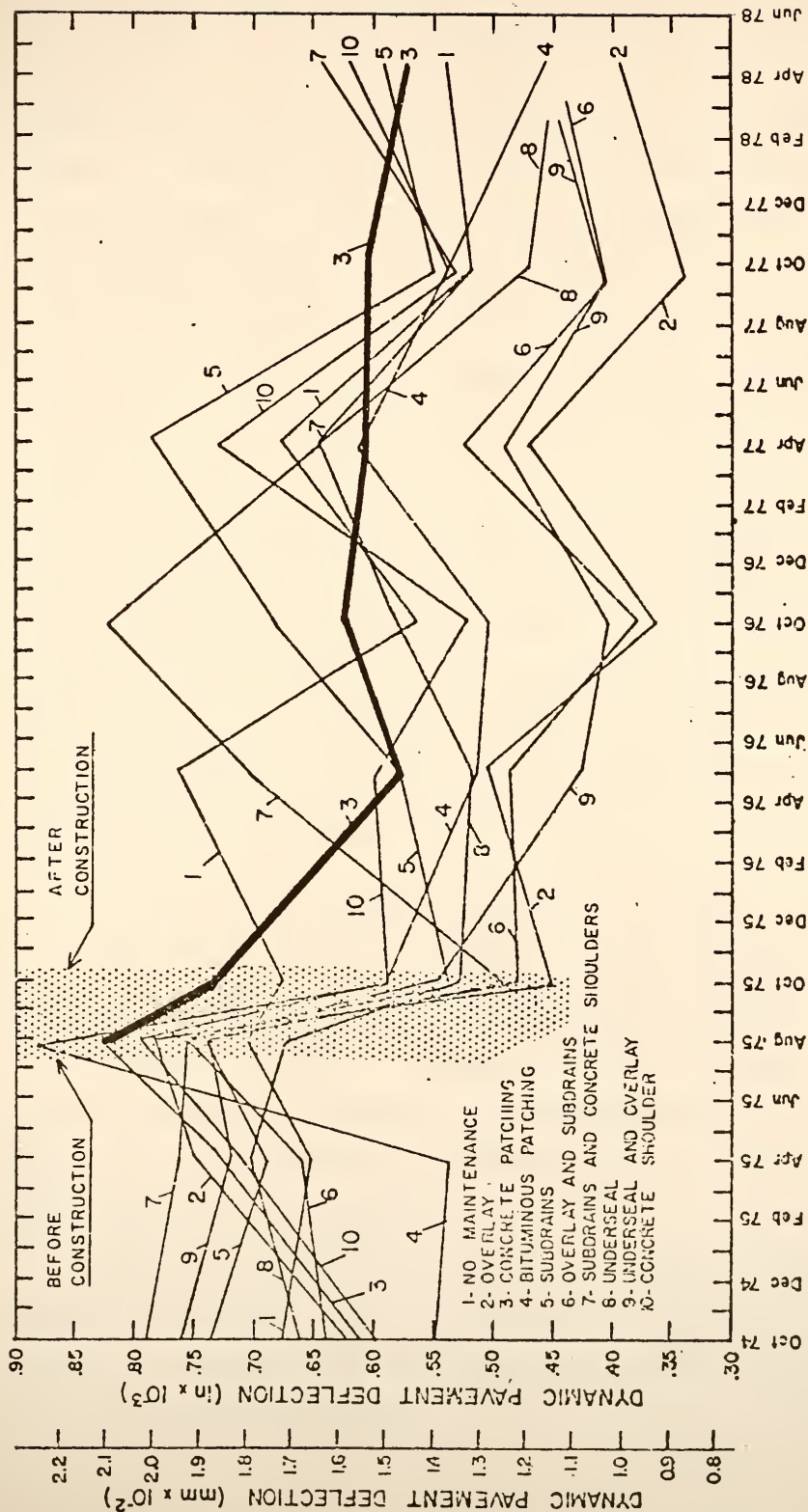


FIGURE 6. MEAN DEFLECTION VS. TIME

failures, 43 were failures at concrete patches and 1 was a failure adjacent to a bituminous patch. In an effort to assist in determining the extent of digout required for patching to preclude failures a series of measurements were made at 27 patches with the Dynaflect to determine if this instrument could be used to detect extent of weakening of the pavement (see Virkler, ref. 10). Figures 7 and 8 show two typical deflection patterns across patches, one in good condition and the other in poor condition.

It is to be noted in Figures 7 and 8 that extent of defect can be detected by means of the Dynaflect; hence, these criteria were adopted in establishing extent of required patching on subsequent patches. After the second year the extent of failures associated with patches decreased markedly suggesting that this testing method is effective. It is one of the recommendations of this study that the use of the Dynaflect to delineate extent of patching be continued.

Statistical Analysis, Deflection vs. Treatment

An Analysis of Variance was performed using the deflection data of the various treatments. Virkler (10) indicated that the analysis of variance was not conclusive in relating deflection with type of treatment. This was because the variability within the test sections was quite high and, therefore, the conclusions are based primarily upon the generalized relationships shown in Figure 6.

Deflection measurements were taken in the spring of 1978 as outlined in the work plan, but due to the uncertainty of the statistical analysis, the performance surveys made in fall of 1978 and spring 1979, did not include deflection tests.

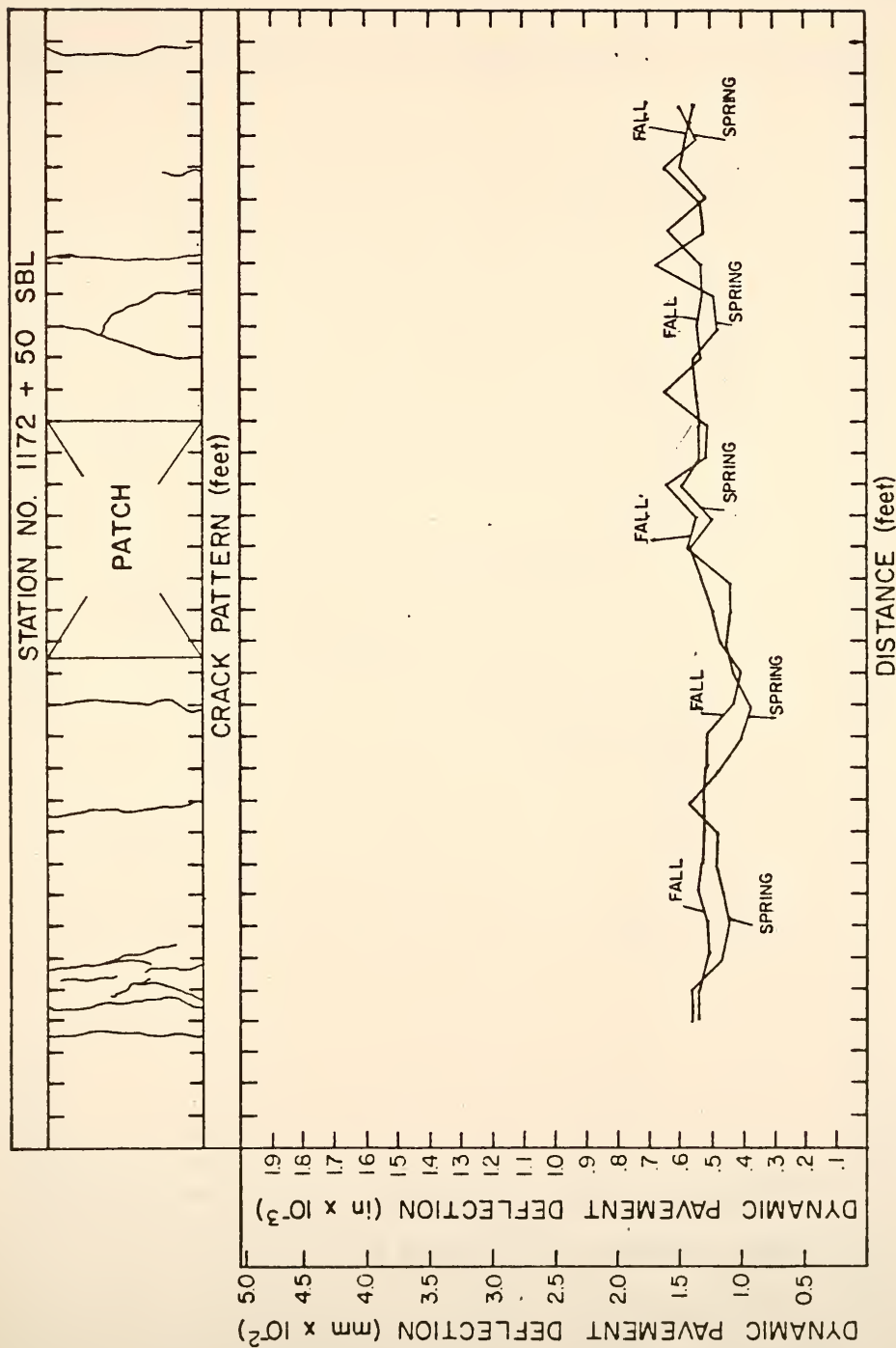


FIGURE 7. DEFLECTION IN VICINITY OF CONCRETE PATCH
IN GOOD CONDITION

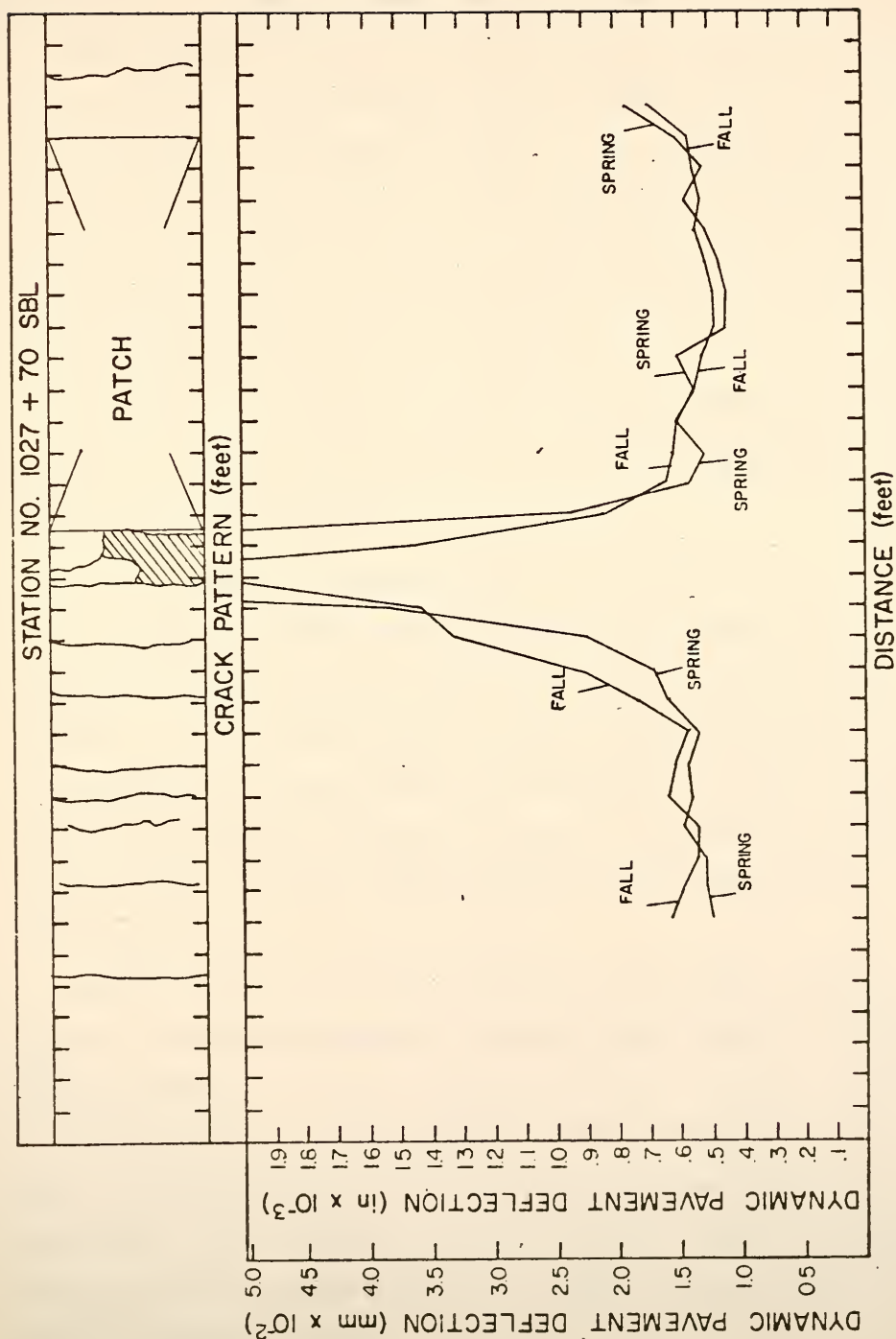


FIGURE 8. DEFLECTION IN VICINITY OF CONCRETE PATCH IN POOR CONDITION

Overlay Thickness and Deflection

On the basis of deflection data, the analysis of variance did not show a statistical difference among deflection values of the various overlay sections on the basis of thickness. This is illustrated in Figure 9 where it is seen that the apparent deflection as measured by the Dynaflect was relatively uniform through fall of 1976 and that the values dropped through autumn of 1977 and that the effect of thickness was nearly obliterated on the later readings.

It was found that none of the overlay thicknesses can be predicted to have lower deflection measurements than the 2 inch thick overlay within the time frame of this study.

Effect of Concrete Shoulder on Deflection

The concrete shoulder sections had many variables within each section. The main variable was whether the concrete shoulder contained a keyway. The only concrete shoulder section containing a keyway is on the southbound lane between stations 1224+00-1212+00. All of the other sections had no keyway and hence, the shoulder was tied to the existing concrete pavement and the pavement-shoulder interface constituted a "butt" type joint.

Another variable involved the spacing of the tie bars. The last variable involved the separation of the joint measurements from the midspan measurements.

There appeared to be some difference between deflections in the keyed and non-keyed joints in the 1976 survey but these differences disappeared in later surveys. The data on the whole showed no significant differences when considering keyways, bar spacing or deflections at joints as compared to midspan.

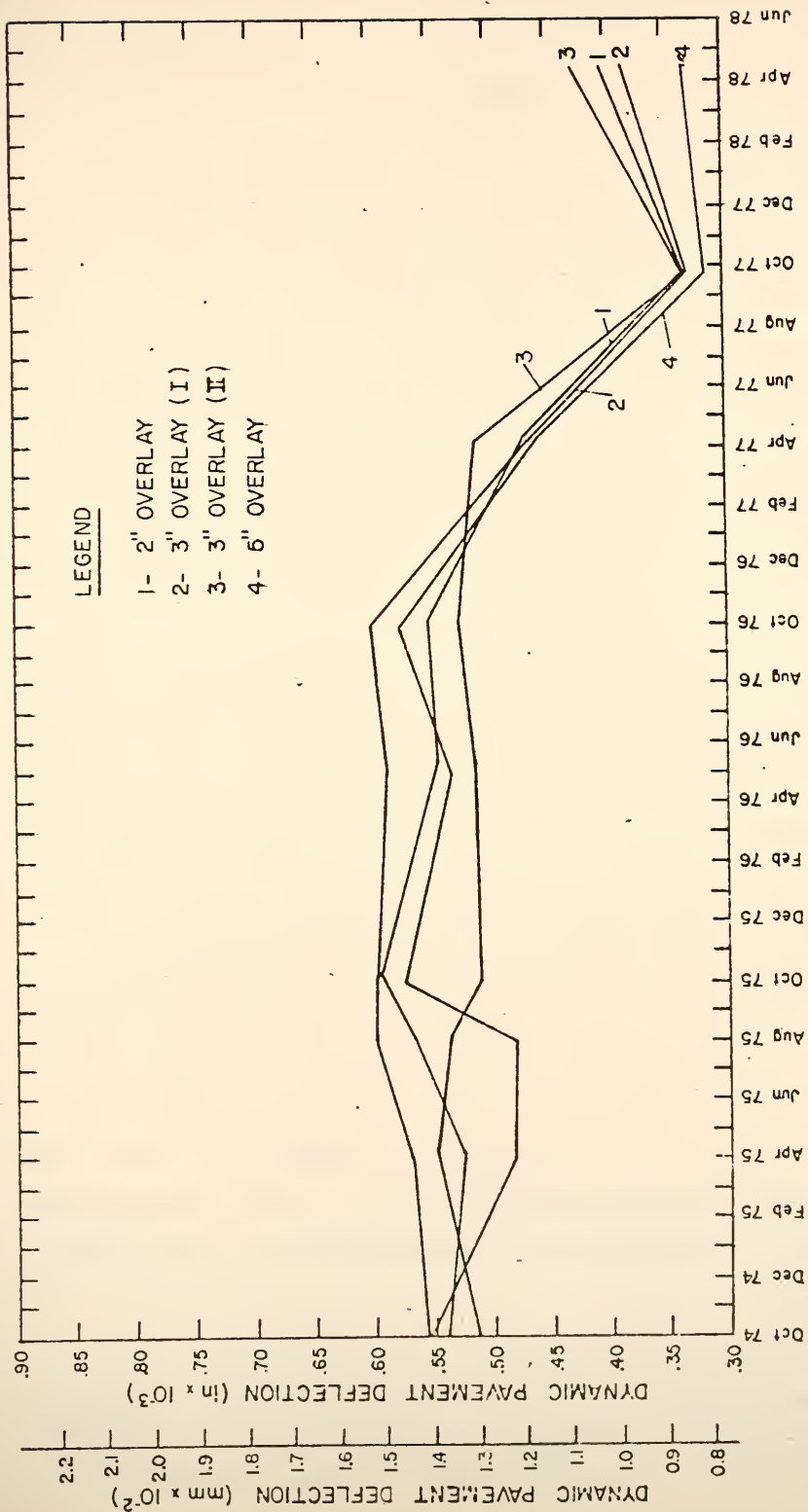


FIGURE 9. MEAN DEFLECTION vs. TIME -
COMBINATION OF OVERLAY SECTIONS

Crack Analysis*

Historically, performance surveys of CRC pavements has been measured, in part at least, by crack interval and type of cracks. For this study only those cracks that were less than 30 inches apart were considered. Figure 2 in previous sections shows typical crack patterns that have been used in the analysis. The distance L of cracking along the pavement edge was in every case the lineal feet of pavement with cracks spacing then 30 inches.

Length of pavement cracked using the criteria in Figure 2 did not increase appreciably during the experiment.

COST ANALYSIS

The cost analysis achieved in this study consisted of an evaluation which indicates the cost effectiveness of the various methods. These data are summarized in Table 8. It is to be seen that the overlay was very effective in stopping the progression of failures although, excluding the concrete shoulder sections, they were the most costly.

The underseal appeared to be a cost effective means of at least slowing down the progression of failures since no failures have been found in those sections that have actually been undersealed.

The subdrain and concrete shoulder sections were found to be the least cost effective means of stopping progression of failures on this particular test section. It is to be recalled, however, that the concrete shoulders and subdrains were used largely on the extreme southern

*Conclusions relative to cracking are correct using the time span of this experiment. Although not a part of this study, as of the time of this writing (April, 1980) visual observations suggest that the extent of cracking has progressed appreciably on some of the sections that have shown considerable amount of failure in the past.

TABLE 8. SUMMARY OF PERFORMANCE DATA

Maintenance Method	Length (ft)	Cost (\$/100')*	Failures per 100 feet through Fall 1977		Failures per 100 feet through Spring 1979	
			In Maint. Section	In Corresponding Control Sections	In Maint. Section	In Corresponding Control Sections
1. Underseal 2" Overlay	2,800	1,436	0	0.545	0	1.000
2. Underseal 3" Overlay	4,000	2,064	0	0.223	0	0.584
3. 2" Overlay	900	1,326	0	0.263	0	0.318
4. 3" Overlay	4,505	1,952	0	0.303	0	0.581
5. 5" Overlay	1,000	2,011	0	0.393	0	0.750
6. Subdrains 3" Overlay	495	2,179	0	0.285	0	0.571
7. Underseal 3" Overlay	3,600	311	0**	0.121	0**	0.316
8. Bit. Patch	800	1,152	0.125	0.25	0.285	0.575
9. Subdrains	5,500	1,008	0.527	.307	1.00	0.635
10. Conc. Should.	2,855	3,010	0.560	0.340	1.96	0.580
11. Subdrains & Conc. Should.	1,455	3,511	0.890	0.285	1.506	0.427
12. Control	20,390	727		0.240		0.505
Totals	48,300	--		0.232		0.542

* Includes cost of patching before constructing maintenance section.

**3 failures have occurred in the Underseal section at locations that were not undersealed. See text for discussion.

end of a construction job where an initial high incidence of failures had taken place, prior to construction of the test pavements.

Construction Costs Compared to Patching Costs

Table 8 illustrates that just seven of the methods were effective in reducing or completely stopping occurrence of failures in the test pavement. These are the first seven listed in the table. It is seen that all but the last of these includes an overlay of asphalt concrete. The last deals with undersealing without the use of an overlay. In the analysis that is presented in Table 9, the last five treatments (No. 8 through No. 12) are excluded.

For the data in Table 9 it is assumed that all of the failures were patched during the life of experience although all the failures were not necessarily patched. It is further assumed that failures occurring during the summer, fall and winter months would be repaired the next construction season. The cost of patching is in 1975 dollars using the average cost of patching for this experiment of \$1515 per patch discounted at the rate of six percent.

All of the sections numerated in this table have shown no failures during the time span of the experiment. The data indicate that the overlay, although very effective in stopping failures, was not cost effective during the period of the experiment when comparing the cost of constructing the maintenance with the average cost of maintaining the pavements shown in the last column of the table. The underseal sections were constructed at an average cost of \$311 per 100 feet and this technique appeared to slow down occurrence of failures. The data

TABLE 9. COST OF MAINTENANCE SECTIONS AND POTENTIAL COST OF PATCHING CONTROL SECTIONS

Maintenance Sections		Cost of Patching Control Sections at End of Year (Dollars per 100 feet)			
Type	Cost (Dollars per 100 ft.)	Year 1	Year 2	Year 3	Year 4
1. Underseal 2" Overlay	1,436	198	521	851	1,283
2. Underseal 3" Overlay	2,064	115	302	504	757
3. 2" Overlay	1,326	62	164	269	407
4. 3" Overlay	1,952	114	302	504	757
5. 5" Overlay	2,011	148	384	638	962
6. Subdrains 3" Overlay	2,179	111	296	485	732
7. Underseal	311	62	164	268	404
AVERAGE	--	116	304	502	757

- NOTES: 1. Patching costs are based on the assumption that all failures are patched and at an average cost of \$1,515 per patch. Costs are accumulated with time.
2. Patching costs are in 1975 dollars discounted at 6%.
3. Time is measured in years after completion of construction in fall of 1975.
4. Costs of maintaining traffic (added user costs) during patching were not considered.

suggest that undersealing is a viable method for slowing down the occurrence of distress in pavements of this type.

SUMMARY

Basically three major types of maintenance were investigated in this research project over and above the normal concrete patching which is done on a routine basis in the state. Various combinations of these maintenance techniques were used and variation of the methods were included in some cases. The basic methods include the following:

1. Overlay with asphalt concrete both with and without drainage and undersealing.
2. Installation of subdrains at the outside edge of the pavement.
3. Concrete shoulders.

The summary which follows is given in the order of most effective to least effective in preventing further deterioration of this specific pavement irrespective of cost. The reader is referred to Table 8 where the cost effectiveness of each of the methods is presented.

1. Asphalt overlay. The asphalt overlay sections have performed very well and no difference has been found in the performance of the overlay relative to the thickness of the overlay itself. No reflection cracking has been noted other than on the "feather sections" where there is a transition from the overlay to a non-overlaid pavement and at two isolated locations where transverse cracks have been seen over known concrete patches. Some surface distortion (i.e. rutting and apparent shoving) has occurred in the asphalt concrete itself.
2. Underseal and overlay. These sections have performed very well and no additional failures have occurred.

3. Overlay and subdrains. Again the pavements with overlay have shown excellent performance and the data do not suggest that the installation of subdrains along with the overlay has aided substantially in the performance of the pavement.
4. Undersealing. Performance of the underseal sections has been quite satisfactory. It is to be recalled that undersealing was actually done only at locations where the deflection was greater than 0.9 mils as measured by the Dynaflect. No failures have occurred where undersealing was done although three have occurred in the underseal sections at locations other than those which were undersealed. The undersealing was done at a cost of \$311 per 100 feet and the data suggest that this is a viable method of preventive maintenance.
5. Bituminous patches. The bituminous patches have shown no distress and no failures have been found associated with the patches. Some settlement has occurred and some roughness is noted in riding over the patches.
6. Subdrains. Numerous failures have occurred on the sections in which subdrains were installed. The subdrains are known to be removing water from under the pavement as evidenced by a decrease in pumping and by visual inspection of the drain outlet. However, the numerous failures in these sections has suggested that additional work could well be done to determine the best means of draining pavements of this type.
7. Concrete shoulders. The concrete shoulders have not performed well and deflection measurements suggest that continued distress might occur. One of the test sections included a

keyway at the pavement edge whereas the others did not. The keyed section has performed very well whereas the non-keyed sections have not.

REFERENCES

1. Yoder, Eldon J. and Asif Faiz, "Evaluation of Continuously Reinforced Concrete Pavements", Report submitted to the Joint Highway Research Project Advisory Board, December 28, 1972.
2. Yoder, Eldon J. and Asif Faiz, "Statewide Condition Survey of Continuously Reinforced Concrete Pavements in Indiana", Report submitted to the Joint Highway Research Project Advisory Board, March 27, 1973.
3. Yoder, Eldon J., and Asif Faiz, "Design and Performance of Continuously Reinforced Concrete Pavements", Proceedings, Purdue Road School, 1973.
4. Faiz, Asif and E. J. Yoder, "Factors Influencing the Performance of Continuously Reinforced Concrete Pavements", Transportation Research Board Record 485, 1974.
5. Yoder, Eldon J., "Primary Factors Influencing Performance of Continuously Reinforced Concrete Pavements in Indiana", Interim Report submitted to the Joint Highway Research Project, June 1974.
6. Faiz, Asif and E. J. Yoder, "Evaluation of Parameters Significantly Influencing the Performance of Continuously Reinforced Concrete Pavements", ACI Publication SP-51, Roadway and Airport Pavements, 1975.
7. Faiz, Asif, "Evaluation of Continuously Reinforced Concrete Pavements in Indiana", Final Report submitted to the Joint Highway Research Project Advisory Board, October 1975.
8. Yoder, Eldon J., Asif Faiz and Donald G. Shurig, "A Comprehensive Pavement Evaluation System: Application to CRCP", Transportation Research Board Record, 1977.
9. Florence, R. H., Jr., "Design and Construction of Several Maintenance Techniques for Continuously Reinforced Concrete Pavements", Joint Highway Research Project Report JHRP-76-12, 1976.
10. Virkler, Stanley J., "Maintenance Methods for Continuously Reinforced Concrete Pavements", Joint Highway Research Project Report JHRP-78-1, 1978.

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